ESRF	**Experiment title:** Capillary waves on a ferrofluid surface under normal magnetic field	**Experiment number:** SI-1496
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Report:
The purpose of the experiment was to study the dynamics of capillary waves on a ferrofluid surface under normal magnetic field. The ferrofluid surface wave modes become unstable above a critical magnetic field B_c. This phenomenon is called "Rosensweig instability" and manifests itself as an ordered pattern of surface protuberance. To study the nature of this transition from the dynamical point of view we used x-ray photon correlation spectroscopy in grazing incidence geometry GIXPCS. The incident angle was $\alpha_i = 0.1^\circ$ to ensure high surface sensitivity. We measured intensity correlation function $g_2(q,\tau) = \frac{\langle I(q,t)\cdot I(q,t+\tau)\rangle}{\langle I(q,t)\rangle^2}$ in the accessible q range 1×10^{-6} – $5\times10^{-6}\mathring{A}^{-1}$. The ferrofluid was placed in a 2mm deep teflon trough, and a perpendicular magnetic field was generated by Helmholtz coils. The strength of the filed was below $B_c \simeq 115G$ to ensure a flat surface. At room temperature T=295K the viscosity η of the ferrofluid is high and the capillary waves are over-damped ($\omega = 0$). In the over-damped regime, all correlation functions were fitted by a simple exponential decay $g_2(q,\tau) = 1 + \beta\exp(-2\Gamma\tau)$, where β is the experimental contrast and Γ the damping constant.
In Fig. 1 the dispersion relation $\Gamma \sim q$ for different strengths of the magnetic field is shown. From the Fig.1 we can see that magnetic field slightly increases the damping constant Γ. This is in agreement with the theoretical prediction. However, according to theory the highest sensitivity to the magnetic field is expected around the transition point from propagating to over-damped behaviour. This transition occurs at a critical wave vector $q_c = \frac{4\sigma\rho}{5\eta^2}$, where σ is the surface tension and ρ is the density of the ferrofluid. q_c can be shifted into the accessible region by adjusting the viscosity η of the liquid.

The ferrofluid used (APG J14) is oilbased and η is adjusted by varying the temperature T. For this purpose a special chamber for liquid samples with a temperature control (243-325° K) was used. We found out that at $T = 319°K$ the q_c in in the middle of the accessible q region Fig. 2. For $q < q_c$ we observe propagating capillary waves and for $q > q_c$ over-damped waves. The correlation functions were fitted with $g_2(q,\tau) = 1 + \beta \exp(-2\Gamma\tau)\cos^2(\omega_p\tau)$, where ω_p is the propagating frequency. In Fig. 2 the experimental (without magnetic field B=0) and theoretical curves are shown. The measured and theoretical transition point q_c are in good agreement. The difference in absolute values of ω_p and Γ are obvious. We suppose that the difference is caused by a resolution effect.

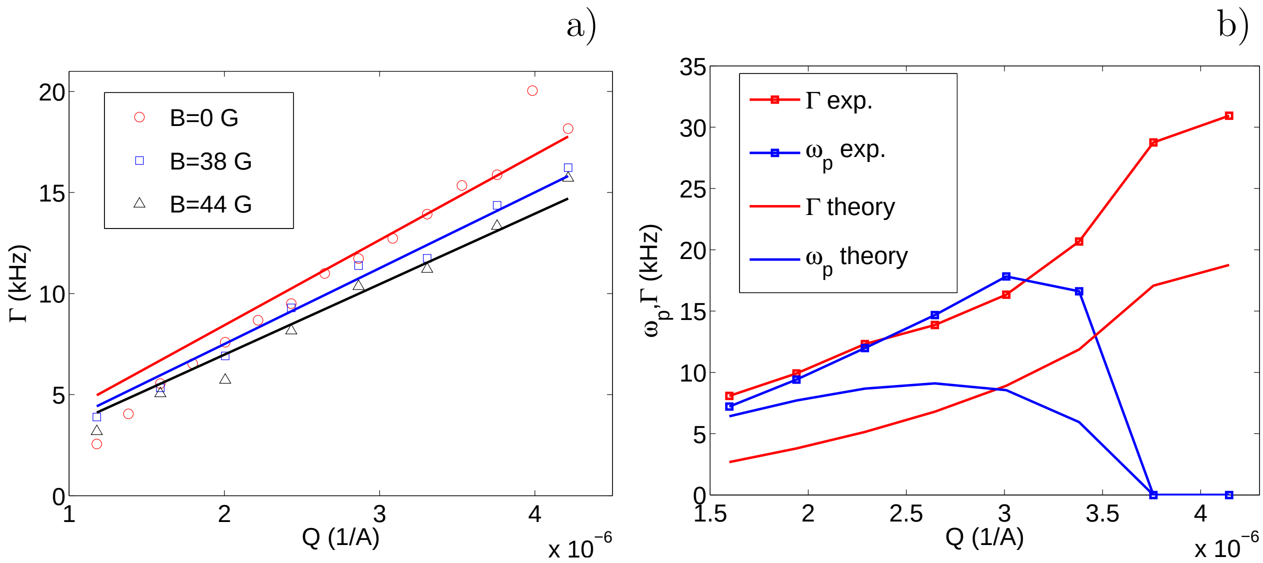

Fig. The surface waves dispersion relations at 295 (a) and 319°K (b). Lines are theoretically calculated curves.

Measurements around the transition point under magnetic field were distorted by unexpected surface irregularities. Inspection of the problem reveled that the metallic trough was causing the surface irregularities. A new trough was made to resolve the above problem.

Our results indicate that the surface dynamics of the ferrofluid is affected by the external perpendicular magnetic field far below B_c above which visible structural surface transformation occurs. It is important to continue the investigations with the improved trough. Understanding of the surface dynamics of ferrofluids at micrometer length scale is needed for future investigation of the dynamics at nanometer scale; the topic of growing interest. At these length scales, the hydrodynamic continuity assumption is no longer valid due to the presence magnetic nanoparticles and hydrodynamics approach doesn't hold.